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SHORT REPORT

Effect of grasshopper availability on the breeding success of the Grey Hypocolius *Hypocolius ampelinus*

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ABSTRACT
The breeding success of the Grey Hypocolius *Hypocolius ampelinus* is mainly determined by local grasshopper density.

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Animal populations are limited by food availability, which is influenced by variation in the environment (White 2008). For example, temperature and rainfall have strong effects on insectivorous bird populations by changing the abundance and phenology of invertebrate food supplies (Dell *et al.* 2005, Both *et al.* 2006, Pearce-Higgins *et al.* 2010, Studds & Marra 2011). This may affect the ability of insectivorous birds to obtain sufficient energy reserves for reproduction and rearing their young (Both *et al.* 2006). Food resources may constrain the reproductive output of birds by limiting the number or quality of offspring fledged in individual nesting attempts, or by limiting the number of nesting attempts during each breeding season (Nagy & Holmes 2005, Illera & Díaz 2006). In order to secure more food for chicks and increase fitness, many bird species are known to coincide their reproductive periods with seasonal peaks of food supply (Cresswell & MacCleery 2003, Chemineau *et al.* 2007). Since many birds are mainly insectivorous, it is important to understand such links between their environment and population demography (Subramanya & Radhamani 1993).

The Grey Hypocolius *H. ampelinus* is a small passerine species and the sole member of the Hypocoliidae family. It is a migratory species that is distributed throughout the Middle East; breeding in Iraq, Iran, Afghanistan, Pakistan and Turkmenistan (Peklo & Sopyev 1980), and wintering mostly in the Arabian Peninsula and on the coasts of the Red Sea and Persian Gulf. Across southwestern Iran, the Grey Hypocolius is typically found in arid and semi-arid areas with patches of vegetation consisting of *Ziziphus* and *Tamarix* bushes.

Although the Grey Hypocolius is a regular breeding bird in the Middle East, including Iran, details regarding its population dynamics, behaviour and ecology remain mostly unknown (Cramp & Simmons 1993, Scott & Adhami 2006). Recently, studies have described its nest site selection in relation to plant structure and breeding success in Iran (Hosseini-Moosavi *et al.* 2014, 2017). However, information about its reproductive biology, food availability and their relationship remain scarce. Cumming (1899) mentioned that the diet of Grey Hypocolius included fruits, berries, mulberries, figs, dates and some insects, while our own previous direct observations indicate that grasshoppers (Orthoptera) are one type of insect used for chick-rearing (Hosseini-Moosavi *et al.* 2011, 2017). In addition, grasshoppers are known to be a key avian food source in many open areas (Capinera 2010). Thus, we aimed to assess the relationship between local grasshopper densities and the breeding success of the Grey Hypocolius.

This study was carried out near the Haft-Tappeh archaeological site (32°4′N 48°21′E, 40–90 m above sea level, 32,000 ha), 90 km north of the city of Ahvaz between the Dez and Karkheh rivers in the northern part of Khuzestan province, Iran. The local weather is influenced by hot and dry plains in the southern parts of Khuzestan with mean temperatures of 3°C in winter and 48°C in summer. The local vegetation is dominated by the shrub *Ziziphus nummullaria*, but other species include *Lycium shawii* in the upper

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canopy, *Prosopis farcta*, *Capparis spinosa* and *Alhagi mannifera* in the middle canopy, and *Medicago radiata*, *Trifolium repens*, *Cynodon dactylon*, *Ephedra foliata*, *Carthamus oxyacantha* and *Cornulaca auchery* as ground cover.

We examined local densities of grasshoppers during the chick-rearing stage of the Grey Hypocolius during the 2011 breeding season. Due to our limited search ability in the large study area of more than 32,000 hectares and scarce nesting attempts of Grey Hypocolius in the disturbed study area due to agricultural activities, we first looked for nest positions and then established transects to maximize the number of nests included in the study. The study area was searched randomly for nests and once a nest was found, nesting sites were recorded, numbered and checked at 2–6 d intervals. After identification of nesting sites, transects were established in May in order to estimate local grasshopper densities using a line transect method (Richards 1953, Marty 1969, Capinera 2010). We divided the study area using random points and stripes with a fixed distance (100 m) to cover all environmental characteristics (especially patches of plant coverage ideal for Grey Hypocolius and its prey) in the west–east direction. In 13 random transects (width = 2 m, mean length = 1799 m), we recorded: number of nests, number of fledglings and number of grasshoppers (Table 1). We used a generalized linear model (GLM) with Poisson distribution to determine the significance of the number of nests, the local density of grasshoppers, and the date of grasshopper survey on the number of fledglings per transect. Since we surveyed the grasshoppers in different transects across different periods of time, we also added the interaction between grasshopper density and the date of grasshopper survey to control for the possible effect of date on grasshopper density. The minimal adequate model was obtained through stepwise removal of the least significant factor until all remaining factors were significant ($P < 0.05$). All statistics were conducted in R version 3.1 (R Core Team 2014).

Across the 13 transects, a total of 23 nests produced 77 eggs and 28 fledglings, and 373 grasshoppers were counted (Table 1). Grey Hypocolius nest building was observed to begin on 11 April while the last observation was on 28 April. The busiest nest building period (57% of pairs) occurred between 17 and 24 April. Eggs were laid between 22 April and 28 May with most being laid between 16 and 28 May. Eggs hatched between 13 May and 3 June with most (76.31%) between 16 and 31 May. The first fledgling was observed on 29 May, the last was observed on 15 June, and the most (89.30%) were observed between 1 and 15 June. Clutch sizes varied from 3 to 5 eggs with a mean of 4.27 (sd = 0.57) while five nests failed before clutch completion, so they were not considered. A mean of 3.45 eggs (sd = 0.68) hatched per nest (total of 37 eggs) from nests that survived to hatching, and a mean of 2.81 (sd = 1.32) chicks fledged (total of 28 chicks) from broods in which at least one chick survived for 30 days.

Direct observations showed that Grey Hypocolius mostly fed on fruits of plant species present in the area such as *L. shawii*, *E. foliata*, and sometimes *C. spinosa*. Besides fruits, Grey Hypocolius was also observed to feed on insects such as butterflies, prior to the seasonal arrival of grasshoppers. The GLM revealed that local grasshopper density was the only significant factor affecting Grey Hypocolius fledging success (Table 2).

Because food abundance and availability affect the reproductive success of birds, they serve as ultimate factors selecting individuals that reproduce at a time most favourable for rearing offspring and for the

Table 1. Grey Hypocolius nests, fledglings and local grasshoppers counts observed in Dez National Park, 2011. Collected data on the phenology of local grasshoppers span the bird breeding season.

Transect	Area (m^2)	Date of grasshopper survey	Number of fledglings	Number of nests	Mean number of fledglings per nest	Number of grasshoppers per transect	Density of grasshoppers (per m^2)
1	3800	May 1	1	1	1	0	0
2	4000	May 15	1	1	1	30	0.0075000
3	4000	May 18	0	2	0	15	0.0037500
4	4000	May 21	0	2	0	16	0.0040000
5	720	May 24	0	2	0	2	0.0027780
6	720	May 27	1	2	0.5	5	0.0069440
7	4400	June 1	5	3	1.67	75	0.0170540
8	4480	June 3	4	2	2	54	0.0120540
9	1930	June 5	3	1	3	6	0.0031090
10	3218	June 7	3	1	3	30	0.0093230
11	4504	June 9	4	2	2	67	0.0148760
12	5792	June 12	4	2	2	66	0.0113812
13	5200	June 15	2	2	1	7	0.0012803
Total	46764	————	28	23	1.22	373	————

Table 2. Summary of general linear models exploring the relationship between the number of nests, grasshopper density and date of grasshopper surveys with the number of fledglings of Grey Hypocolius in Dez National Park, 2011. A stepwise process was used to produce the minimal adequate model.

	Number of fledglings per transect			
	Estimate	se	*Z*-value	*P*-value
Maximum model				
Intercept	−1.418	1.449	−0.979	0.328
Number of Nests	−0.327	0.402	−0.813	0.416
Grasshopper Density	182.655	214.741	0.851	0.395
Date of Grasshopper Survey	0.054	0.042	1.298	0.194
Grasshopper Density ~ Date of Grasshopper Survey	−2.016	5.622	−0.359	0.720
Minimal adequate model				
Intercept	−0.246	0.422	−0.584	0.559
Grasshopper Density	114.712	36.124	3.176	0.001**

survival of those offspring to the next breeding season (Baker 1938, Bourgault *et al.* 2009). In this study, we focused on a single food item, grasshoppers, and how its density relates to the number of offspring fledged from Grey Hypocolius nests. Our results showed a significant effect of local grasshopper density on the total number of chicks fledged from nests in each transect. Grasshoppers first appeared in May but did not reach peak abundance until June (Table 1). Most Grey Hypocolius eggs were laid in the second half of May and most fledglings (25 out of 28 fledged chicks) left their nests between 1 and 15 June after a mean incubation time of 15 days (Hosseini-Moosavi *et al.* 2014). The Grey Hypocolius chick-rearing period of 17–20 days thus directly coincides with peak local grasshopper abundances, which suggests that grasshoppers are an important food item for rearing fledglings. Overall, our observations are consistent with the hypothesis that the Grey Hypocolius attempts to take advantage of peak grasshopper abundances through the timing of chick-rearing.

Our results are also consistent with studies on other bird species that revealed clear relationships between food availability and breeding parameters. For example, Blue Tits *Cyanistes caeruleus* in an area dominated by evergreen Holm Oaks *Quercus ilex*, where local food sources were scarce, were found to respond to increasing food availability by advancing their date of egg laying by about one week (Bourgault *et al.* 2009). Another study showed a significant positive correlation between the timing of Great Tit *Parus major* egg laying and the timing of local caterpillar abundance (Van Noordwijk *et al.* 1995). Similar findings were reported for Savannah Sparrows *Passerculus sandwichensis*, which revealed bigger clutch sizes, greater breeding success, and larger nestlings when grasshoppers were more abundant (Miller *et al.* 1994). Another study on the Western Kingbird *Tyrannus verticalis* indicated that sites with larger average insect biomass showed earlier egg laying, larger clutch sizes, faster nestling growth rates and higher chick survival rates (Blancher & Robertson 1987). It is hypothesized that, at higher insect densities, adult birds spend less time searching for quality food and thus nestlings are fed more often and are provided with greater nutrition, resulting in a greater proportion of fledged chicks.

From a total of 77 eggs found in nests, only 28 chicks fledged in the 2011 breeding season. This high mortality rate of 64% (52% as eggs and 12% as nestlings) is close to the approximately 50% mortality rate of Grey Hypocolius from Karkheh National Park, Iran as reported by Askari (2013). While the cause of the observed high mortality is not definitively known, one reason could be high temperatures, which reached 50°C during the breeding season when shade over the nest from plants was minimal (Hosseini-Moosavi *et al.* 2017). Because of limitations in time and limited accessibility of the area, we could not directly study the diet of the Grey Hypocolius chicks in detail. Future studies should aim to identify preferred food items in relation to all possible available food sources and their phenology in order to assess their relative importance towards breeding success. Technologies such as camera trapping and genetic sampling of nestling feaces should be useful in this regard. Environmental factors such as vegetation phenology and social interactions should also be considered. Regardless, the relationship between grasshopper density and reproductive performance in the Grey Hypocolius is interesting and warrants further investigation.

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